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Title: Plant Fertilizer Compositions Containing
Phosphonate and Phosphate Salts, and Derivatives Thereof

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Cross-Reference to Related Application

The present invention is a continuation-in-part of co-pending Serial Number 08/705,594 filed on August 30, 1996.

Background of the Invention

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The present invention is broadly concerned with fungicidal compositions, and methods of use, which provide improved efficacy in controlling parasitic fungi in plants. More particularly, the compositions and methods of use of the invention include fungicidally effective amounts of both phosphate, preferably in the form of either mono, di, tri or dipotassium phosphate (KH_2PO_4 , K_2HPO_4) and phosphonate, preferably in the form of either mono or dipotassium phosphonate (KH_2PO_3 , K_2HPO_3), in aqueous solution.

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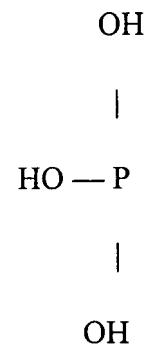
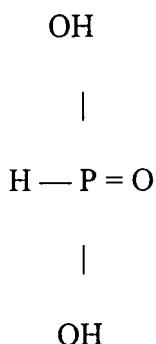
According to another aspect of the present invention, the compositions and methods of use of the invention include growth response effective amounts of both phosphate, preferably in the form of either mono or dipotassium phosphate (KH_2PO_4 , K_2HPO_4) and phosphonate, preferably in the form of either mono or dipotassium phosphonate (KH_2PO_3 , K_2HPO_3), in aqueous solution.

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Phosphorus is an essential major element in plant nutrition because it governs the energy producing reactions, including those that are oxidative, and photophosphorylative and the production of adenosine diphosphate (ADP) and adenosine triphosphate (ATP). Energy-rich phosphate bonds of ADP and ATP provide the energy for many of the physiological reactions that occur in plants.

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The element phosphorous appears in two general forms that concern the present invention — phosphonate and phosphate. The term "phosphonate," sometimes also referred to as "phosphite," means the salts (organic or inorganic) of either phosphonic acid or phosphorous acid. Phosphonic and phosphorous acids have the formula H₃PO₃ and a molecular weight of 82.00. Their structures from the International Union of Pure and Applied Chemistry are shown below:



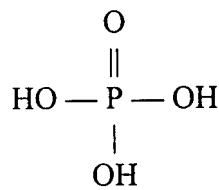
Phosphonic Acid

CA: 13598-36-2

Phosphorous Acid

CA: 10294-56-1

The term "phosphate" means the salts (organic or inorganic) of phosphoric acid having the formula H₃PO₄, molecular weight of 98, and has the following structure:



Phosphoric Acid

CA: 7664-38-2

In the past, various phosphonate compounds have been proposed as useful in fungicidal and fertilizer compositions for application to plants. See, e.g., U.S. Patent Nos. 4,075,324 and 4,119,724 to Thizy, describing phosphorous acid, its inorganic and organic salts, as a plant fungicide; U.S. Patent No. 4,139,616 to Dueret, describing fungicidal compositions based on phosphorous acid esters and salts thereof; U.S. Patent No. 4,542,023 to Lacroix et al., describing organophosphorus derivatives as possessing systemic and contact fungistatic and fungicidal activity; U.S. Patent Nos. 4,698,334 and 4,806,445 and 5,169,646 to Horriere et al., describing fungicidal compositions based on alkyl phosphonates; U.S. Patent Nos. 4,935,410 and 5,070,083 to Barlet, describing fungicidal aluminum tris-alkyl-phosphonate compositions; and U.S. Patent No. 5,514,200 to Lovatt, describing formulations of phosphorous-containing acid fertilizer for plants. (The teachings of the proceeding U.S. Patents are hereby incorporated by reference.) The above references disclose phosphonate compositions have been found to be effective for protecting plants, and particularly grape vines, citrus and fruit trees and tropical plants, against fungal attack.

Once assimilated, phosphonates have been shown to enhance the phytoimmune system. The phosphonate induced stimulation of the phytoimmune system is triggered by the induction of ethylene production, followed by a rapid accumulation of phytoalexins at the site of infection. Phosphonates have also been shown to have detrimental effect on the growth of Phycomycetes. See, Pegg, K.G. and deBoer, R.F., "Proceedings of the Phosphonic (Phosphorous) Acid Work Shop, *"Australasian Plant Pathology*, Vol. 19 (4) 1990.

In accordance with this development of the present invention, however, it has recently been discovered that phosphonates exacerbate the non-target Ascomycete fungi, and

other fungi producing an eiphytic outbreak of much greater magnitude than the infections occurring without phosphonate treatment. This phenomenon is known as pathological acerbation.

In the past, phosphates were not viewed as a solution to pathological acerbation of Ascomycete fungal infections. This is because phosphates are viewed primarily as a fertilizer with only limited, or even detrimental, fungal properties. For example, U.S. Patent 5,514,200 teaches that phosphate fertilizers inhibit beneficial symbiosis between plant roots and mycorrhizal fungi, and further promote bacterial and fungal growth in the rhizosphere, including the growth of pathogenic fungi and other small soil-borne organisms. (Col. 2, lines 18-28). Phosphates have also been considered to be a competitive inhibitor for phosphonate assimilation, thus inhibiting the ability of phosphonates to protect against fungus attack. See, Pegg, K.G. and deBoer, R.F., "Proceedings of the Phosphonic (Phosphorous) Acid Work Shop, *"Australasian Plant Pathology*, Vol. 19 (4), pp. 117 and 144, 1990. Yet further, phosphonates and phosphates were believed to be "biological strangers," with the presence of phosphonates or its esters, exerting little or no influence on enzyme reactions involving phosphates. Robertson, H.E. and Boyer, P.D., "The Biological Inactivity of Glucose 6 — phosphonate, Inorganic Phosphites and Other Phosphites," *Archives of Biochemistry and Biophysics*, 62 pp. 380-395 (1956).

Accordingly, the requirements for a successful phosphonate-based fungicide depend on the elimination of the phosphonate-induced pathological acerbation of Ascomycete fungal infections.

Moreover, the prior art teaching that phosphates and phosphonates are "biological strangers" is relevant to the lack of teaching of use of a composition of both for any agricultural use.

Summary of the Invention

The present invention addresses the problems outlined above, and provides an improved anti-fungicidal composition for plants that contains, as active ingredients, fungicidally effective amounts of both phosphonates and phosphates. According to the present invention, it has been discovered that the application to a plant of the inventive phosphonate/phosphate composition substantially eliminates pathological acerbation of Ascomycete fungi, while at the same time, provides a means to control Phycomycetes and Ascomycetes and other fungi with a single product.

Thus, an object of present invention is to provide a fungicidal composition for protection for plants against fungal infection, especially Phycomycetes and Ascomycetes.

Another object of the invention is to provide such anti-fungal protection with a single product that upon application does not cause pathological acerbation of Ascomycetes infections.

A further object of the invention is to provide a method of treating plants and to provide anti-fungal protection in plants against attack by Phycomycetes, Ascomycete and other fungi and bacteria.

A yet further object of the invention is to provide an anti-fungal composition for treating plants that is environmentally safe, inexpensive to use and has low mammalian toxicity.

These and other objects of the invention are attained by the invention disclosed below. According to the invention, anti-fungicidal compositions for the protection of plants, especially citrus and fruit trees and vines against fungus attack, preferably contain as an active material a fungicidally effective amount of at least a first salt formula selected from the group consisting of KH_2PO_3 , K_2HPO_3 , and K_3PO_3 , and at least a second salt selected from the group consisting of KH_2PO_4 , K_2HPO_4 and K_3PO_4 , in a mixture with an agriculturally acceptable carrier.

The composition preferably comprises an aqueous solution wherein each salt is present in solution from about 20 millimole to about 5% vol./vol..

According to another aspect of the invention, the amount of the first salt is one part by weight and the amount of the second salt is between 0.001 and 1,000 parts by weight.

Phosphonate salts useful in the practice of the invention also include those organic and inorganic salts taught by U.S. Patent Nos. 4,075,324 and 4,119,724 to Thizy et al., (see, e.g., col. 1, ln. 51-69 through col. 2, ln. 1-4).

The present invention, in another aspect, also has been found to be effective as a growth stimulator or fertilizer for plants, and addresses the problems in the art with regard to finding effective fertilizers. Thus, the present invention provides a means for applying a single product to plants which is both an effective fungicide and an effective fertilizer.

It is therefore an object of this aspect of the invention to present a composition and method of use which functions as a fertilizer for plants.

A further object of this aspect of the invention is to function as a fertilizer which provides substantial growth response results.

Another object of this aspect of the invention is to function as a fertilizer which is ecologically and human compatible, is economical, and is efficient.

These and other objects, features and advantages of the invention will become more apparent with reference to the accompanying specification and claims.

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A Detailed Description of the Preferred Embodiments.

The following examples set forth preferred concentrations and techniques for formulation thereof, as well as methods of application and use and test results demonstrating the efficacy of the inventive concentration in protecting plants against attack by Ascomycete and Phycomycete fungi. It is to be understood, however, that these Examples are presented by way of illustration only and nothing therein shall be taken as a limitation upon the overall scope of the invention. The specific components tested in the Examples were prepared and applied as follows.

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Method of Preparation

15 A. Potassium Phosphonate (KH_2PO_3) Aqueous Solution. H_3PO_3 is produced by the hydrolysis of phosphorus trichloride according to the reaction: $\text{PCl}_3 + 3\text{H}_2\text{O} > \text{H}_3\text{PO}_3 + 3\text{HCl}$. The HCl is removed by stripping under reduced pressure and the phosphonic acid (H_3PO_3) is sold as a 70% acid solution.

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The phosphonic acid is then neutralized in aqueous solution by potassium hydroxide according to the reaction: $\text{H}_3\text{PO}_3 + \text{KOH} > \text{KH}_2\text{PO}_3 + \text{H}_2\text{O}$ to about pH 6.5 and to produce a 0-22-20 liquid weighing 11.15 lbs./gal. This solution is commercially available and is sold under the trademark "Phos-Might" by Foliar Nutrients, Inc., Cairo, GA 31728.

B. Potassium Phosphate (K₂HPO₄) Aqueous Solution. Mono potassium phosphate (0-51.5-34) is reacted with 45% potassium hydroxide in aqueous solution to produce dipotassium phosphate by the following reaction: This solution is commercially available and is sold under trademark "K-Phos" by Foliar Nutrients, Inc., Cairo, GA 31724

5 KH₂PO₄ + KOH > K₂HP0₄ + H₂O with a product density of 1.394 at 20 C and a solution pH of 7.6 producing a 0-18-20 analysis.

C. KH₂PO₃/K₂HPO₄ Solution. Varying amounts of each compound (K₂HPO₃;KH₂PO₃; K₂HPO₄; or KH₂PO₄) in aqueous solution are combined at rates ranging from 20 millimole to 5% vol./vol., depending on crop host and the pathogen complex and level of infection.

10 Method of Application

The preferable method of application is foliar, either by ground or aerial equipment, but is not limited to that method alone. Injection or soil applications, for example, could also be efficacious depending on specific crops and pathogens.

15 The inventive compositions have utility on fruit crops, agronomic crops, ornamentals, trees, grasses, vegetables, grains, and floricultural crops, as well as, some aquatic crops including water cress.

The fungicidal properties of the compounds according to the invention are various, but are particularly interesting in the case described in the following examples:

20 Examples 1-5 exemplify a portion of these applications. In Examples 1-4, fungicidal treatments were applied to ornamentals, citrus and vegetables. In each of Examples 1-4,

treatments were applied as a one gallon solution by a back pack sprayer, maintained at about 60 psi, in sufficient quantities of water to achieve thorough coverage.

All treatments were applied to the appropriate number of experimental units assigned in a randomized complete block (RCB) design replicated four times. Example #5 was a pre-
5 harvest fungicidal spray evaluation on "Nova" tangelos.

As used in the examples, "percent infection" means percent of leaves that exhibit fungus lesions. "Phytotoxicity" means number crop injury to leaves that fell off the plant following the application of the solution.

The Ascomycete fungi were the subjects of testing in Examples 1 through 5 and are
10 all members of the Ascomycete family.

EXAMPLE NO. 1

Dogwood\Powdery Mildew Fungicide Trial Trail Ridge Nursery, Keystone Hts., Florida

15 The compounds according to the invention are studied for the effect on the powdery mildew (*Oidium Spp.*), which is responsible for foliar infections in dogwood.

Potassium phosphonate and potassium phosphate solutions were applied in compositions as set forth in Table 1 below. An average of 5 six-inch pots per experimental
20 unit with 4 repetitions in a randomized complete block ("RCB") design were considered. The solutions were applied to Dogwood (*Cornis Florida Var. "Weaver"*). The application of the compositions were made in April 25, 1996, May 8, 1996, and May 23, 1996. The effects of the various compositions were rated on May 30, 1996.

Table 1 shows that when a potassium phosphonate solution (containing no appreciable amount of phosphate) is applied to dogwood, pathological acerbation of the Ascomycete fungus occurs in 100 percent of the dogwood leaves, in contrast to the control, which exhibited only 30 percent infection. The inventive composition that combine potassium phosphate and potassium phosphonate showed a complete elimination of the pathological acerbation phenomenon, and in fact, dropped the amount of infection by about 20 percent.

TABLE 1

TREATMENT	RATE/100 gal.	*%INFECTION	PHYTOTOXICITY
1) POTASSIUM PHOSPHONATE SOLUTION	1%	100	0
2) POTASSIUM PHOSPHATE SOLUTION	1%	0	0
3) POTASSIUM PHOSPHONATE SOLUTION + POTASSIUM PHOSPHATE SOLUTION	1%	10	0
4) POTASSIUM PHOSPHATE SOLUTION	2%	0	0
5) CONTROL	-	30	0

EXAMPLE NO. 2

Shumard Oak/Powdery Mildew Fungicide Trial
Trail Ridge Nursery, Keystone Hts., Florida

5 In Example No. 2, the inventive compositions were tested for effectiveness against the powdery mildew (*Phyllactinia corylea*) that infects shumard oak (*Quercus shumardii*).

In Example No. 2, an average of ten 3-gallon plots per experimental unit with 4 repetitions in a randomized complete block design were examined.

10 .. When only potassium phosphonate solution was applied, the percentage of infection increased to 40 percent, compared to a 20 percent infection in the control, indicating a pathological acerbation of the Ascomycete fungi. When the inventive composition including potassium phosphonate and potassium phosphate was applied, the infection was completely eliminated.

15 TABLE 2

TREATMENT	RATE/100 gal.	*%INFECTION	PHYTOTOXICITY
1) POTASSIUM PHOS- PHONATE SOLUTION	1%	40	0
2) POTASSIUM PHOS- PHATE SOLUTION	1%	0	0
3) POTASSIUM PHOS- PHONATE SOLUTION + POTASSIUM PHOS- PHATE SOLUTION	1%	0	0
4) POTASSIUM PHOS- PHATE SOLUTION	2%	0	0
5) CONTROL	-	20	0

EXAMPLE NO. 3

Citrus Alternaria Fungicide Trial
Kerr Center, Vero Beach, Florida

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In Example No. 3, the inventive composition was tested for effectiveness in citrus trees (*Alternaria citri*) that were infected with the fungi.

As used in Table No. 3 below, "% Y.L.D." means percent young leaf drop, and "% Y.F.D." means percent young fruit drop. %Y.L.D. and %Y.F.D. were determined by examining 4 terminals/tree with 4 repetitions in a randomized complete block design. The date on which the compositions were applied were March 21, 1996. The compositions were rated on April 2, 1996. When only potassium phosphonate solutions were applied, %Y.L.D. and %Y.F.D. increased from 6.2 and 1.5 to 23.9 and 37.9, respectively, indicating pathological acerbation of the Ascomycete fungi. Application of the inventive composition not only eliminated the acerbation, but showed an improvement in Y.L.D. and Y.F.D.

TABLE 3

<u>TREATMENT</u>	<u>RATE/100 gal.</u>	<u>%Y.L.D.</u>	<u>%Y.F.D.</u>	<u>PHYTOTOXICITY</u>
1) POTASSIUM PHOSPHATE SOLUTION	0.5%	5.2	3.8	0
2) POTASSIUM PHOSPHATE SOLUTION	1 %	2.5	2.5	0
3) POTASSIUM PHOSPHATE SOLUTION	2 %	1.5	1.0	0
4) POTASSIUM PHOSPHONATE SOLUTION	1 %	23.9	37.5	0

5	5) POTASSIUM PHOS- PHATE SOLUTION + POTASSIUM PHOS- PHONATE SOLUTION	0.5% + 0.5%	2.2	3.7	0
	6) CONTROL	-	6.2	1.5	0

10 EXAMPLE NO. 4

Carrot/*Alternaria* Fungicide Trial

In Example No. 4, carrot plots were inoculated with *Alternaria dauci* fungi. The plot sizes were single rows X 25 feet X 4 repetitions in a RCB design. The dates that compositions were applied were February 2, 9, 15, 22, and March 8, 14, 22, and 28, 1996. The fungi infections were rated on April 5 and April 23, 1996. The second rating was 25 days after the last fungicide application. The test took place at Sanford, Florida.

Application of the inventive solutions including potassium phosphonate and potassium phosphate improved the extent of infection from that otherwise occurring in the control carrots. Although the solution making use of only potassium phosphonate caused a slight improvement from the infection occurring in the control, it was substantially less than that associated with the inventive composition.

Also shown in Example No. 4 is a comparison of the effectiveness of the inventive composition to other fungicides, including Cu-Alexin and Fe-Alexin. This test demonstrates that the inventive composition is as effective as other well known fungicides, but without being as environmentally toxic.

TABLE 4

	<u>TREATMENT</u>	<u>RATE/100 GAL.</u>	<u>AVG% INFECTION</u>	
			<u>4/5/96</u>	<u>4/23/96</u>
5	1) POTASSIUM PHOSPHATE SOLUTION	1%	6.9	8.2
10	2) POTASSIUM PHOSPHONATE SOLUTION	1%	18.7	28.8
15	3) POTASSIUM PHOSPHATE SOLUTION + POTASSIUM PHOSPHONATE SOLUTION	0.5% +	8.9	10.7
20	4) Cu-ALEXIN	0.2 lb ai	8.8	11.6
25	5) Fe-ALEXIN	0.2 lb ai	12.7	12.9
30	6) CONTROL	-	23.0	34.8

EXAMPLE NO. 5

Citrus Preharvest Spray Trials
Kerr Center, Vero Beach, Florida

In Example No. 5, twenty-two fruits, each from five nova tangelo trees, were randomly selected and marked. The fruits were scuffed with an emery board and then sprayed with the compositions set forth below in Table 5, with five treatments on the same day. Seven days later, the fruit was picked and stored for two weeks in sealed white plastic bags, then examined for penicillium mold.

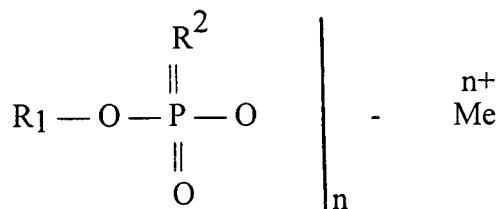
The degree of infection was rated using following scores: 0 = no infection, 1 = light infection (less than 30% coverage), 2 = severe infection (100% coverage). The degree of infection is the mean of scores from 22 fruit.

5 TABLE 5

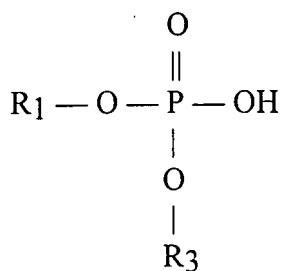
	<u>TREATMENT</u>	<u>RATE</u>	DEGREE OF <u>INFECTION</u>	<u>#ROTTEN FRUIT</u>	<u>PHYTOTOXICITY</u>
10	1) POTASSIUM PHOSPHONATE SOLUTION	1%	1	9	0
15	2) POTASSIUM PHOSPHONATE SOLUTION	2%	0.91	12	0
20	3) POTASSIUM PHOSPHATE SOLUTION	1%	0	0	0
25	4) POTASSIUM PHOSPHATE SOLUTION + POTASSIUM PHOSPHONATE SOLUTION	0.5% 0.5%	0.27	3	0
30	5) CONTROL	-	1.41	12	0

The above Examples demonstrate that the inventive compositions are useful in protecting plants against attack by Phycomycete , Ascomycete and other fungi and bacteria with the application of one solution.

It will also be appreciated that compositions for controlling Phycomycete and Ascomycete fungi diseases in plants may also contain phosphate and phosphonate compounds comprising a fungicidally effective amount of at least a first salt having the following formula:



And a second salt having the following formula:



Where R_1 is selected from group consisting of H, K, an alkyl radical containing from 1 to 4 carbon atoms, halogen-substituted alkyl or nitro-substituted alkyl radical, an alkenyl, halogen-substituted alkenyl, alkinyl, halogen-substituted alkinyl, alkoxy-substituted alkyl radical, ammonium substituted by alkyl and hydroxy alkyl radicals;

R_2 and R_3 are selected from a group consisting of H and K;

Me is selected from a group consisting of K, alkaline earth metal cations, aluminum atom; ammonium cation; and

n is a whole number from 1 to 3, equal to the valence of Me.

It will be appreciated that foliar applications of the inventive compositions will be effective as a common agricultural practice to control root pathogens caused by *Phytophthora*, *Phythium*, and foliar infections caused by *Plasmopara*.

It will also be appreciated that the inventive compositions will have biocidal and arthropod pest control activity, and also have fertilizer effects, in plants. (See e.g., U.S. Pat. Nos. 5,206,228, 5,133,891 and 5,514,200).

According to another aspect of the invention, compositions including both potassium phosphate and potassium phosphonate have been found to produce substantial growth response in certain plants. Table 6 below is illustrative:

TABLE 6

FOLIAR NUTRITIONAL EVALUATIONS OF K-PHOS AND PHOS-MIGHT ON RHAPHIOLEPIS INDICA

TREATMENT	RATE	No. of Shoots/Rep.				AVG
		A	B	C	D	
1) POTASSIUM PHOSPHONATE SOLUTION	1%	22	13	20	15	17.5
2) POTASSIUM PHOSPHATE SOLUTION	1%	28	23	25	32	27.0
3) POTASSIUM PHOSPHONATE SOLUTION	1/2%	23	26	24	8	20.3
POTASSIUM PHOSPHATE SOLUTION	+ 1/2%					

4) POTASSIUM PHOSPHATE SOLUTION	2%	24	38	32	24	29.5
5) CONTROL-	--	4	1	7	3	3.8

Experimental units = 3 x 3 gallon containers x 4 repetitions with treatments assigned in a randomized complete block design. Application dates for treatments A-D were approximately one, two, four, and three weeks apart respectively (October 31, 1996; November 7, 1996; November 20, 1996, December 19, 1996, and January 8, 1997 respectively; rated January 14, 1997).

As can be seen by Table 6, all four nutritional treatments provided growth responses greater than the untreated control, and K-PHOS at 1% and 2% were superior to PHOS-MIGHT at 1% and the combination of 1/2% each of PHOS-MIGHT + K-PHOS. The combination, however, produced substantially higher growth responses than the control, in fact, on a level similar to the individual treatments of K-PHOS or PHOS-MIGHT. The higher growth responses, compared to the control, can be expected when the inventive composition of Potassium Phosphate salt and Potassium phosphonate salt aqueous solution wherein each said salt is present in solution from about .25% vol./vol. to about 3.0% vol./vol., and preferably between .5% vol./vol. and 2.0% vol./vol. It is theorized that the unexpected growth responses are due to the slow conversion of PO_3 in the inventive composition to PO_4 after application. This composition further provides the added benefit of being fungicidal as well.

The disclosures in all references cited herein are incorporated by reference.